Procurement Executive, Ministry of Defence

The Weathering of Plastics Materials in the Tropics

6 The Further Evaluation of a Solar Radiation Concentrating Device (EMMA) as a Means of Accelerating the Weathering of Plastics

by

Procurement Executive, Ministry of Defence/British Plastics Federation Joint Committee on Behaviour of Plastics Materials under Tropical Conditions

1981

Propellants, Explosives and Rocket Motor Establishment
Waltham Abbey
Essex

PROCUREMENT EXECUTIVE, MINISTRY OF DEFENCE

Weathering of Plastic Materials in the Tropics: Part 6

Further Evaluation of a Solar Radiation Concentrating Device (EMMA) as a means of Accelerating the Weathering of Plastics

by

PROCUREMENT EXECUTIVE, MOD/BRITISH PLASTICS FEDERATION
JOINT COMMITTEE ON BEHAVIOUR OF PLASTICS MATERIALS UNDER TROPICAL CONDITIONS

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CORRIGENDUM

Front cover and Title Page

Author - For "Joint Committee on the Behaviour of Plastics Materials under Tropical Conditions" read -

"Joint Working Party on the Ageing and Weathering of Polymers and Composites".

Page 15 Table VI should read -

Exposure Time Weeks	Temperate Control	EMMA	EMMAQUA A	EMMAQUA B	45^{o} Static Rack
0	60.3	-	-	-	-
2	59.4	59.8	59.8	59.0	-
4	58.4	57.4	57.8	57.8	58.3
6	) 60.2	58.6	58.3	58.3	-
7	)	-	-	-	57.7
8	62.8	57.7	57.4	58.4	-
13	60.7	-	-	-	NY
16	61.9	NY	NY	NY	-
26	58.8	-	-	-	NY
52	61.5	-	-	-	NY

NY: No Yield

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SUMMARY

This report is an account of a second trial conducted at Desert Sunshine Exposure Test Inc. using the facility of the EMMA and EMMAQUA machines which are reported to accelerate natural weathering. Low density polyethylene and polyacetal specimens were tested and no real acceleration factors could be found for the EMMA machines over natural 45° deg. exposure.

1 INTRODUCTION

Some years ago the Joint Sub-Committee (Ministry of Defence and British Plastics Federation) initiated a trial to assess the claims made for "accelerated natural weathering" by Desert Sunshine Exposure Tests Inc. of Phoenix, Arizona who had developed systems for increasing the intensity of solar radiation falling on test specimens exposed throughout the day.

The materials selected for this trial were a low density polyethylene and an acetal copolymer.

Specimens of these materials were exposed on the EMMA radiation concentrating device and static racks at 45^{o} to the horizontal facing south. At the end of pre-determined exposure periods, specimens were returned to the UK for physical testing. Details of the materials used, specimen types, exposure schedules and the test results are given in the report of the trial.[1]

The conclusions of the report were that similar changes in mechanical properties occurred for both exposure modes and the effects were produced in samples exposed on EMMA at least twice as fast as those exposed on the 45^{o} racks. In the case of changes in appearance the similarities were less marked. No firm quantitative comparison could be made between the two exposure modes because the exposure periods for the specimens on the static racks were too long for the rate of degradation which occurred.

It was felt that a further trial would be necessary in order to establish a clearer correlation between exposure on the 45^{o} racks and the EMMA. In this second trial exposure on EMMAQUA was also included. This is a modified EMMA system which provides an intermittent water spray.[2]

As with the first trial DSETI kindly provided free exposure facilities.

The same grade of low density polyethylene as was used in the earlier trial and a homopolymer polyacetal, rather than a copolymer, were exposed in a new trial which commenced on 31 March 1977. At the end of each exposure period specimens were returned to PERME and MQAD for visual assessment and mechanical testing. Details of materials, specimens and exposure schedules together with the results and conclusions from this trial are described below.

2 MATERIALS AND SPECIMENS

2.1 Materials

Two materials were used, as outlined in the introduction. Details of these are shown below in Table 1.

TABLE 1

Materials

Polymer	Trade Name	Grade/Colour	Supplier	Additives
Polyethylene	Alkathene	11* natural	ICI Ltd	0.2% N-n' diβ Naphthyl-p phenylene diamine
Polyacetal	Delrin	500 natural	Nylonic Engineering Ltd	Not known

*Previously known as WJG 11

2.2 Polyethylene Specimens

Sheets 300 mm square and 1.5 mm thick were compression moulded and annealed by a method corresponding to that described in BS 3412 (1976). One such sheet for each withdrawal period was cut into four 125 mm square panels, one each for the "accelerating" devices and one control. One larger sheet for each withdrawal was also cut into two 300 x 100 mm panels, one for natural exposure and one for a control.

From the withdrawn panels dumb-bell specimens were cut using a cutter meeting the requirements of BS 903 Part A2 (Type E).

2.3 Polyacetal Specimens

The polyacetal specimens were machined from commercially available extruded sheet material to an ERDE dumb-bell design[3], Figure 1. The previous trial was conducted on injection moulded dumb-bells but as these often have stresses moulded in during manufacture it was decided preferable to use more uniform specimens cut from sheet. Care was taken to machine all specimens in the same direction from the sheet material.

3 EXPOSURE

The exposure schedule is reproduced in Appendix 1. Phoenix, the area in which this work was carried out, is one of the few areas in the world which receive on average more than 4,000 hours sunshine a year (compared with the UK range of 1,000 to 1,400 hours). If specimens are so mounted on exposure that they are normal to the direct rays of the sun all day then they will receive more total solar radiation than statically mounted specimens.

3.1 The EMMA and EMMAQUA

The method of mounting specimens such that they follow the sun is known as an Equatorial Mount. At the Desert Sunshine Exposure Tests site they have developed an Equatorial Mount with Mirrors for Acceleration (EMMA) and one with mirrors plus water spray (EMMAQUA).

The ten mirrors on the EMMA are a special finish aluminium and they are claimed[4] to reflect from 70% to 80% of the ultra violet radiation and about 85% of the total solar radiation. Each machine has a guidance system, powered by solar energy, which keeps the mirrors facing the sun at 90° all day. Blowers on each machine force air over and under the samples so that their surface temperatures are about the same as they would be if they were exposed on conventional racks at 45° facing the equator.

The facility of spraying the specimens with water on the EMMAQUA was also used in this trial although it was not in the first one. Two spray schedules were used, schedule A which is the standard spray condition and schedule B which is an experimental spray cycle which is claimed to provide a better correlation with weathering data obtained from exposure sites in Florida.

3.2 Exposure Sites

In all four exposure sites were used at Phoenix

(i) EMMA

(ii) EMMAQUA Schedule A

(iii) EMMAQUA Schedule B

(iv) Static exposure at 45° facing the equator

Control specimens were retained in the UK for testing with each batch of withdrawn specimens.

3.3 Withdrawal Periods

The specimens exposed on the "accelerating" machines, that is EMMA, EMMAQUA schedules A and B, were withdrawn from exposure after periods of 2,4,6,8, and 16 weeks. The specimens exposed on the static 45^{o} racks were withdrawn after periods of 4,7,13,26 and 52 weeks. These periods were based, in part, on the previous trial results and also in the expectation that the specimens on static exposure would take longer to show the effects of degradation.

4 TEST METHODS

The interval between withdrawal of specimens by DSET and receipt at the UK test laboratories was usually two weeks or more. After receipt all specimens were conditioned (23^{o}C 50% rh) for approximately 48 hours prior to testing.

4.1 Test Methods for Polyethylene Specimens

4.1.1 Visual assessment

Specimens were examined for colour change, loss of gloss, cracking and chalking.

4.1.2 Tensile properties

Measurements of tensile properties of both the control and the exposed specimens were carried out according to BS 2782 Method 320A (1976) except that dumb-bells were of a shape corresponding to BS 903 Part A2 Type 2. A minimum of eight specimens from each panel were tested. In addition, values for the material immediately after moulding, termed "initial values", were also determined from the scrap material remaining after cutting the panels for exposure. In this case a minimum of four replicates per 300 mm square sheet were tested.

Properties measured were: tensile stress at yield, tensile stress at break and elongation at break.

The dumb-bells were measured for the mean cross sectional area in the gauge length and were tested on an Instron Universal Testing Machine (Model TT-CM) at a crosshead rate of 500 mm/min. Elongations were measured by dividers from white paint marks 25 mm apart applied to the gauge length of each specimen.

4.2 Test Methods for Polyacetal Specimens

4.2.1 Visual assessment

Due to an experimental oversight there are no visual assessment results on the polyacetal specimens.

4.2.2 Tensile properties

In general five replicates were tested. The width and thickness of each specimen was determined to the nearest 0.01 mm in the parallel gauge length portion. The specimens were then loaded to failure on a Monsanto Tensometer Type E at a constant crosshead rate of 5 mm/min. The load/extension data was recorded autographically. A 1 inch gauge length Instron extensometer, capable of 10% extension, was used to determine the strain of the specimens up to 10%. Strains higher than this have been quoted as "greater than 10%".

The yield strength, breaking strength, tensile modulus, elongation at yield and elongation at break were calculated. A typical chart record with the various points discussed in this section is shown in Figure 2.

4.2.3 Tensile Impact of Polyacetal

The equipment used for the tensile impact tests was a modified Avery Izod pendulum impact machine. This is a high energy pendulum system which carries the specimen in the pendulum head and continuously records load and deformation behaviour to fracture under impact conditions.[5]

The rate of testing was 1,000 mm/sec. A typical record of the test is shown in Figure 3. The strength was calculated as for a slow speed tensile test and the stiffness was defined as:

$$\text{stiffness} = \frac{100}{b\ d\ D}$$

where b = width in mm

d = thickness in mm

D = deflection of pendulum

Note: D was determined from a tangent drawn to the load/deflection curve. The full scale load was the same in every case and in this arbitrary definition of

stiffness the load was not introduced into the formula. The results obtained, however, allow a valid comparison of stiffness of the specimens. The energy to break of the specimens was determined from a tell-tale pointer which followed the swing of the pendulum. As a cross-check of the validity of this measurement some energy values were also determined by measuring the area under the load/deflection curve.

4.3 Solar Radiation Measurements

Records of total solar radiation in Langleys (cal/cm^2) were provided by DSET for all of the exposure conditons. Additionally records were provided of ultra-violet sun hours (UVSH) for the static racks. An UVSH is defined as any sixty minutes when the intensity of the solar radiation exceeds 0.823 Langleys per minute.[6]

5 RESULTS

5.1 Exposure Conditions

All exposures were commenced on 31st March 1977 and the final withdrawal of the specimens on the static racks was made on 30th March 1978. The total solar radiation and UVSH recorded are shown in Table II.

TABLE II

Total Solar Radiation and UVSH

Exposure period weeks	Total Solar Radiation Langleys		UVSH Static Racks
	EMMA & EMMAQUA	Static Racks	
2	70,860	-	-
4	132,370	15,990	168
6	196,530	-	-
7	-	27,370	283
8	249,970	-	-
13	-	48,760	501
16	495,970	-	-
26	-	93,720	972
52	-	176,200	1828

The specimens on the EMMA and EMMAQUA received approximately nine times the total solar radiation received by specimens on the static racks. This is a similar ratio to that observed in the first trial.

5.2 Visual Assessment

5.2.1 Polyethylene

Changes in the visual appearances of the polyethylene samples were so slight as to preclude any attempt at ranking them against a scale. The only visual changes which could be detected were as follows:

a. Specimens subjected to accelerated exposure (EMMA, EMMAQUA 'A' and EMMAQUA 'B')

Some very slight yellowing and loss of gloss could be seen on the specimens subjected to the maximum exposure (5th withdrawal). The EMMA specimens were slightly more affected than those exposed using the EMMAQUA 'A' or EMMAQUA 'B' system. No difference could be detected between the two EMMAQUA systems.

b. Specimens subjected to natural exposure

Some very slight yellowing and loss of gloss could be observed with the specimens from both the 4th and 5th withdrawals.

5.3 Tensile Results of Polyethylene

The mean results are shown in the following tables. A complete set of results is shown in Appendix 2.

TABLE III

Tensile Yield Strength in MPa of Polyethylene

Exposure Time Weeks	Panels for accelerated exposure					Panels for natural exposure		
	Initial Value	Retained Control	EMMA	EMMAQUA A	EMMAQUA B	Initial Value	Retained Control	45° Static Rack
2	9.9	10.6	10.5	10.3	10.5	-	-	-
4	10.0	10.8	11.5	11.1	11.1	10.1	10.9	10.9
6	9.9	10.8	11.3	11.2	11.2	-	-	-
7	-	-	-	-	-	10.3	10.5	10.8
8	10.1	10.7	10.7	10.6	10.3	-	-	-
13	-	-	-	-	-	10.2	10.6	10.9
16	10.0	10.9	NY	NY	NY	-	-	-
26	-	-	-	-	-	10.1	11.5	13.3
52	-	-	-	-	-	10.0	10.4	NY

TABLE IV

Tensile Breaking Strength in MPa of Polyethylene

Exposure Time Weeks	Panels for accelerated exposure					Panels for natural exposure		
	Initial Value	Retained Control	EMMA	EMMAQUA A	EMMAQUA B	Initial Value	Retained Control	45° Static Rack
2	12.6	11.7	12.8	12.9	12.1	-	-	-
4	12.0	12.2	12.5	11.9	12.5	12.1	12.7	12.8
6	12.5	11.7	11.5	12.9	12.0	-	-	-
7	-	-	-	-	-	12.6	12.2	11.3
8	12.3	11.3	10.8	10.9	11.1	-	-	-
13	-	-	-	-	-	11.9	11.8	9.1
16	12.0	11.8	11.7	11.2	11.3	-	-	-
26	-	-	-	-	-	12.2	11.3	11.1
52	-	-	-	-	-	12.4	11.6	12.8

TABLE V

Elongation at Break in % of Polyethylene

Exposure Time Weeks	Panels for accelerated exposure					Panels for natural exposure		
	Initial Value	Retained Control	EMMA	EMMAQUA A	EMMAQUA B	Initial Value	Retained Control	45° Static Rack
2	690	550	550	590	550	-	-	-
4	660	570	540	530	560	680	610	600
6	680	620	570	560	550	-	-	-
7	-	-	-	-	-	680	550	540
8	680	550	520	500	530	-	-	-
13	-	-	-	-	-	680	580	66
16	670	590	40	50	20	-	-	-
26	-	-	-	-	-	680	580	50
52	-	-	-	-	-	680	700	50

5.4 Tensile Results of Polyacetal

The mean results are shown in the following tables. A complete set of results are shown in Appendix 3.

TABLE VI

Tensile Yield Strength in MPa of Polyacetal

Exposure Time Weeks	Temperate Control	EMMA	EMMAQUA A	EMMAQUA B	45^{o} Static Rack
0	60.3	-	-	-	-
2	59.4	59.8	59.8	59.0	-
4	58.4	57.4	57.8	57.8	58.3
6 7	60.2	58.6	58.3	58.3	-
8	62.8	57.7	57.4	58.4	-
13	60.7	-	-	-	NY
16	61.9	NY	NY	NY	-
26	58.8	-	-	-	NY
52	61.5	-	-	-	NY

NY: No Yield

TABLE VII

Elongation at Yield in % of Polyacetal

Exposure Time Weeks	Temperate Control	EMMA	EMMAQUA A	EMMAQUA B	45° Static Rack
0	10.0	-	-	-	-
2	12.2	9.43	9.81	9.10	-
4	11.0	8.56	8.66	9.14	9.21
6	10.6	8.33	8.20	8.16	-
7		-	-	-	7.66
8	10.3	7.59	6.79	8.05	-
13	10.8	-	-	-	NY
16	10.2	NY	NY	NY	-
26	5.91	-	-	-	NY
52	9.30	-	-	-	NY

NY: No Yield

TABLE VIII

Tensile Breaking Strength in MPa of Polyacetal

Exposure Time Weeks	Temperate Control	EMMA	EMMAQUA A	EMMAQUA B	45° Static Rack
0	58.7	-	-	-	-
2	56.3	58.5	59.1	59.0	-
4	54.6	56.3	57.0	56.7	58.3
6	57.3	56.7	57.2	56.5	-
7		-	-	-	56.7
8	57.3	56.8	57.4	57.2	-
13	57.9	-	-	-	43.6
16	57.8	29.4	31.0	31.9	-
26	55.1	-	-	-	35.4
52	58.8	-	-	-	36.4

TABLE IX

Elongation at Break in % of Polyacetal

Exposure Time Weeks	Temperate Control	EMMA	EMMAQUA A	EMMAQUA B	45° Static Rack
0	>10	-	-	-	-
2	>10	>10	>10	>10	-
4	>10	>10	>10	>10	>10
6	>10	>10	>10	>10	-
7		-	-	-	>10
8	>10	>10	8.76	>10	-
13	>10	-	-	-	3.34
16	>10	1.16	1.54	1.37	-
26	>10	-	-	-	1.43
52	>10	-	-	-	2.15

TABLE X

Tensile Modulus in GPa of Polyacetal

Exposure Time Weeks	Temperate Control	EMMA	EMMAQUA A	EMMAQUA B	45° Static Rack
0	2.53	-	-	-	-
2	2.67	2.64	2.52	2.60	-
4	2.46	2.52	2.43	2.47	2.54
6	2.46	2.64	2.54	2.70	-
7		-	-	-	2.61
8	2.52	[illegible]	2.30	2.44	-
13	2.50	-	-	-	2.51
16	2.46	2.80	2.87	2.62	-
26	2.64	-	-	-	2.71
52	2.60	-	-	-	3.05

5.5 Tensile Impact Results of Polyacetal

The mean results of the tensile impact results are shown in the following tables. Full sets of results are shown in Appendix 3.

TABLE XI

Tensile Impact Strength in MPa of Polyacetal

Exposure Time Weeks	Temperate Control	EMMA	EMMAQUA A	EMMAQUA B	45^{0} Static Rack
0	78.0	-	-	-	-
2	) 84.3	65.6	80.6	48.5	-
4	)	33.4	38.7	34.1	77.9
6	82.5	32.3	32.2	30.9	-
7	83.0	-	-	-	48.4
8	83.3	30.6	30.8	30.6	-
13	83.4	-	-	-	24.8
16	84.7	20.2	22.0	24.0	-
26	82.3	-	-	-	20.6
52	79.2	-	-	-	15.9

TABLE XII

Impact Energy to Break in Nm of Polyacetal

Exposure Time Weeks	Temperate Control	EMMA	EMMAQUA A	EMMAQUA B	45^{0} Static Rack
0	7.5	-	-	-	-
2	) 6.2	0.9	2.1	0.3	-
4	)	0.1	0.1	0.1	1.9
6	3.2	0.1	0.1	0.1	-
7	6.0	-	-	-	0.5
8	6.4	0.1	0.1	0.1	-
13	7.2	-	-	-	0.1
16	5.9	0	0	0	-
26	7.6	-	-	-	0
52	6.7	-	-	-	0

TABLE XIII

Impact Stiffness of Polyacetal

Exposure Time Weeks	Temperate Control	EMMA	EMMAQUA A	EMMAQUA B	45^{o} Static Rack
0	2.0	-	-	-	-
2	2.19	2.13	2.12	2.21	-
4		2.15	2.24	2.14	2.19
6	2.27	2.33	2.30*	2.29	-
7	2.26	-	-	-	2.23
8	2.34	2.45	2.43*	2.39*	-
13	2.29	-	-	-	NM
16	2.37	NM	NM	NM	-
26	2.21	-	-	-	NM
52	2.12	-	-	-	NM

NM: Not Measurable

* : Mean of results that were measurable, one or two in each batch not measurable.

6 MECHANICAL TESTING RESULTS AND DISCUSSION

6.1 Polyethylene

Changes observed in the tensile yield strength of specimens on exposure, both on the "accelerating" devices and the static racks, were small up to the point where the polyethylene became brittle and the yield point disappeared.

No changes in the tensile breaking strength of polyethylene were detected because of the greater scatter in the results.

Only minor changes in elongation at break were detected before the onset of embrittlement which reduced the elongation to about 10% of its initial 550-600% value. This phenomenon occurred on both the "accelerated" exposures (EMMA and EMMAQUA) and on the natural static exposures. Embrittlement took place on the "accelerated" exposures between 8 and 16 weeks, ie between approximately 250-496 kilo Langleys. The embrittlement on natural exposure took place between 7 and 13 weeks, probably nea.er the 13 week time interval, ie approximately 27-49 kilo Langleys.

Thus the only major change in the tensile behaviour of this particular grade of low density polyethylene was a sudden embrittlement, as shown by the reduction of the elongation at break and the disappearance of the yield point. Comparing the "accelerated" with the natural exposure there appears to be little, if any, difference between them when assessing the results on a time scale despite the vast difference in radiation dosage.

6.2 Polyacetal

The tensile yield strength and elongation at yield of polyacetal showed no major changes before the specimens became brittle, irrespective of the exposure mode. The tensile breaking strength of all polyacetal specimens also remained virtually unchanged until embrittlement when the strength dropped by up to 50%. This was accompanied by increasing scatter in the results. The elongation at break followed a similar pattern. No change was apparent in the tensile modulus results.

Embrittlement of the tensile test specimens occurred between the 8 and 16 week withdrawals on the "accelerated" exposure and between the 7 and 13 week withdrawals on the static exposure, the same time scale as for the polyethylene.

The tensile impact strength of all the "accelerated" specimens had dropped by the first withdrawals and of the natural exposure specimens by the second withdrawal and continued to decrease on following withdrawals. Apart from the 2 week exposure period these results indicate little difference between the three "accelerated" exposure conditions. The apparent differences at two weeks could well be due to the scatter inherent in impact testing.

The energy to break the polyacetal specimens in tensile impact dropped drastically by the time the first withdrawals were made. The very low values of 0 and 0.1 Nm as read off the scale were confirmed by determining the area under the load/displacement trace.

The impact stiffness of all the specimens remained virtually unchanged until the time when the specimens had been shown to be brittle in the tensile tests. It was then not possible to determine the impact of stiffness from the records.

As with the polyethylene, the polyacetal specimens show little or no difference, on a time scale, between the four exposure conditions.

6.3 Discussion of Results

The tensile test results of this trial show no real distinction between the static exposure and exposure on the "accelerating" devices, EMMA, EMMAQUA 'A' and EMMAQUA 'B'. Embrittlement of both the polyethylene and the polyacetal occurred between the 8 and 16 week withdrawals for the "accelerated" tests between 7 and 13 weeks for the natural exposure. It is not possible to give any acceleration factor. A different choice of exposure periods to cover more adequately the ductile-brittle transition of both materials might have given more conclusive information.

There is some evidence that the rate of loss of tensile impact strength differs between the static exposure and the "accelerating" devices with the latter producing a 50% loss in 4 weeks and the former a 40% loss in 7 weeks. This indicates an acceleration factor of approximately 2 which is of the same order as found in the earlier trial. It should be noted, however, that the test method which showed this factor in the first trial showed no acceleration in this second trial.

Overall there is little firm evidence that the use of the EMMA and EMMAQUA give an acceleration in the weathering of the materials tested. Both materials became brittle within the same timescale but at vastly different solar radiation levels, approximately nine times higher on the "accelerating" devices than on the static racks.

It is important to consider why a high acceleration factor, as suggested by the radiation levels, was not achieved when both the materials exposed are primarily degraded outdoors by photolytic processes. It is possible that differences in the quality of radiation between the exposure methods could account for this.

The total solar radiation falling on the earth consists of about 50% infra-red, 5% ultra-violet and the remaining portion other wavelengths. It is the ultra-violet (UV) portion of the solar spectrum which is important in the

degradation of polymeric materials. Work on monitoring this portion has shown that the global solar UV has two components, direct and diffuse, and that the latter is the major component.[7]

The materials on the 45° static racks are exposed to direct and diffuse UV. The materials on the EMMA would, however, only have the direct UV component reflected onto them and even then the mirrors are not 100% efficient. It is therefore highly likely that although the materials on the EMMA receive approximately 9 times the total solar radiation received by the materials on the static racks they receive a lower increase in UV. This is confirmed by unpublished work[8] where polymeric films were used to monitor the UV on the EMMA and the static racks. It was found that samples on the EMMA receive only approximately 3 times the amount of UV incident on the 45° racks.

However, the rate of degradation of the two materials tested on the "accelerated" EMMA machines was not apparently increased when at least a tripling in the degradation rate would have been expected.

7 CONCLUSIONS

In this trial a polyacetal homopolymer and a low density polyethylene were exposed on sun following and concentrating devices, EMMA and EMMAQUA, and on static racks at 45° to the horizontal, facing the equator. No clear evidence of acceleration was observed.

Both materials became brittle in approximately the same time, between 7 and 16 weeks, for all modes of exposure although there were vast differences in radiation dosage.

Neither this trial nor the first have shown that there is any significant benefit to be gained in using EMMA and EMMAQUA instead of natural exposure for the materials and test methods used.

8 ACKNOWLEDGEMENTS

The assistance of the staff at MQAD, MOD(PE) Woolwich in conducting the work on polyethylene, and the staff at PERME, MOD(PE) Waltham Abbey in conducting the work on polyacetal is gratefully acknowledged.

9 REFERENCES

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APPENDIX 1

PIT Comm Ref CJ/16/022- (282)
PERME WAM 87/03

Title

DESERT SUNSHINE EXPOSURE TESTS, INC PHOENIX
EMMA, EMMAQUA A AND B - 45^{o} COMPARISON

Joint Sponsors:	MQAD (Plastics) Royal Arsenal Woolwich London SE18	for PIT Committee
	PERME (NM) Waltham Abbey Essex EN9 1BP	

1 Purpose

To define the acceleration factors of the EMMA, EMMAQUA Schedules A and B for:

(1) a polyolefin;

(2) a polyacetal;

compared to a normal exposure at 45^{o} to the horizontal.

2 Material

2.1 Polyolefin - Alkathene Grade 11 - natural ex ICI Ltd (= WJG-11)

Four 5 in x 5 in squares
or Two 12 in x 4 in squares cut from 12 in x 12 in compression moulded sheet. Annealed 10 mins in boiling water.

2.2 Polyacetal - Delrin 500 Natural

ERDE dumb-bells milled from sheet.

3 Shape

3.1 Polyolefin

3.1.1	Plaque	5 in x 5 in	EMMA
3.1.2	"	5 in x 5 in	EMMAQUA Schedule A
3.1.3	"	5 in x 5 in	EMMAQUA Schedule B
3.1.4	"	5 in x 5 in	Stored Control
3.1.5	"	12 in x 4 in	Normal Exposure 45^{o}
3.1.6	"	12 in x 4 in	Stored Control

3.2 Polyacetal

3.2.1 ERDE Double Shouldered Dumb-bell

4 Exposure

4.1 EMMA

4.2 EMMAQUA Schedule A

4.3 EMMAQUA Schedule B

4.4 Stored Control

4.5 Normal Exposure 45° facing the equator

4.6 Normal Exposure Stored Controls

All control specimens will be held at PERME under Standard Test Conditions.

Identification marks to be on the unexposed face.

5 Scope

5.1 Polyolefin

Key to designated code.

P - denoted polyolefin (all panels)

M - 5 in sq panels for EMMA accelerated schedule

QA - 5 in sq panels for EMMAQUA type A schedule

QB - 5 in sq panels for EMMAQUA type B schedule

C - 5 in sq panels for retained controls (held at MQAD)

NE - 12 in x 4 in larger panels for inclined (45°) normal exposure schedule

C - corresponding 12 in x 4 in controls (held at MQAD)

5.2 Polyacetal

D - denoted polyacetal (Delrin)

M - frames for EMMA

QA - frames for EMMAQUA Schedule A

QB - frames for EMMAQUA Schedule B

NE - frames for 45° exposure

C - controls; tested at each withdrawal; (held at PERME)

Panels and frames are numbered 1 - 5, panel 1 to be withdrawn after the first period (eg panel designated p-QA3 is therefore a polyolefin from EMMAQUA Schedule A withdrawn after the 3rd period).

In the case of the polyolefin panels which are cut from 12 in sq sheets, sets of panels for one withdrawal are to be cut from one sheet:

eg 1: PM2, PQA2, PQB2 and PC2 5 in sq panels to be cut from one sheet;
eg 2: PNE4, and PC4 12 in x 4 in panels to be cut from one sheet, etc.

6 Withdrawals

6.1 EMMA, EMMAQUA Schedules A and B
Period 2, 4, 6, 8 and 16 weeks

6.2 45^{o} Exposure
Period 4, 7, 13, 26 and 52 weeks

7 Assessment

7.1 Polyolefin

7.1.1 Visual (in UK)

To include all surface defects
eg cracking, crazing, erosion and chalking

7.1.2 Mechanical (Tensile Properties)

Tested to BS 2782 Method 301F - Dumb-bell Type 2 BS 901 A2
Recording (1) Tensile Strength at Yield
(2) Tensile Strength at Break
(3) Elongation at Break

7.2 Polyacetal

7.2.1 Visual (in UK)

As for 7.1.1

7.2.2 Mechanical (Tensile Properties)

Tested to BS 2782 Method 301J using ERDE Dumb-bell
Recording (1) Tensile Strength at Yield
(2) Tensile Modulus
(3) Elongation at Yield
(4) Tensile Strength at Break
(5) Elongation at Break

7.2.3 Mechanical (High Speed Impact)

Using Avery Pendulum Impact Tester
Recording (1) Tensile Strength at Break
(2) Stiffness
(3) Energy to break

8 Meteorological Data

8.1 Routine Site Met Data

8.2 Solar Radiation

9 Report

Final by PIT Committee

APPENDIX 2

LOW DENSITY POLYETHYLENE - TENSILE RESULTS

"ACCELERATED" EXPOSURES

Type of Exposure \ Mechanical Prop	2 weeks			4 weeks			6 weeks			8 weeks			16 weeks		
	TS (Y) (MPa)	TS (B) (MPa)	E (%)	TS (Y) (MPa)	TS (B) (MPa)	E (%)	TS (Y) (MPa)	TS (B) (MPa)	E (%)	TS (Y) (MPa)	TS (B) (MPa)	E (%)	TS (Y) (MPa)	TS (B) (MPa)	E (%)
Initial Values	9.9 ± 0.2	12.6 ± 0.6	690 ± 30	10.0 ± 0.5	12.0 ± 0.7	660 ± 60	9.9 ± 0.2	12.5 ± 0.4	680 ± 35	10.1 ± 0.3	12.3 ± 1.5	680 ± 30	10.0 ± 0.5	12.0 ± 0.8	670 ± 15
Retained Controls	10.6 ± 0.1	11.7 ± 1.0	550 ± 45	10.8 ± 0.2	12.2 ± 1.1	570 ± 20	10.8 ± 0.2	11.7 ± 1.1	620 ± 45	10.7 ± 0.4	11.3 ± 0.9	550 ± 35	10.9 ± 0.2	11.8 ± 0.8	590 ± 30
EMMA	10.5 ± 0.5	12.8 ± 1.3	550 ± 35	11.5 ± 0.1	12.5 ± 0.6	540 ± 20	11.3 ± 0.3	11.5 ± 1.8	570 ± 40	10.7 ± 0.4	10.8 ± 1.4	520 ± 35	- -	11.7 ± 0.1	< 40
EMMAQUA 'A'	10.3 ± 0.4	12.9 ± 0.7	590 ± 20	11.1 ± 0.1	11.9 ± 1.4	530 ± 65	11.2 ± 0.2	12.9 ± 1.5	560 ± 20	10.6 ± 0.5	10.9 ± 1.0	500 ± 35	- -	11.2 ± 0.3	< 50
EMMAQUA 'B'	10.5 ± 0.1	12.1 ± 1.6	550 ± 40	11.1 ± 0.2	12.5 ± 1.5	560 ± 25	11.2 ± 0.4	12.0 ± 1.6	550 ± 55	10.3 ± 0.3	11.1 ± 1.6	530 ± 35	- -	11.3 ± 0.2	< 20

The limits shown are 95% confidence levels.

NATURAL EXPOSURES

Type of Exposure \ Mechanical Prop	4 weeks			7 weeks			13 weeks			26 weeks			52 weeks		
	TS (Y) (MPa)	TS (B) (MPa)	E (%)	TS (Y) (MPa)	TS (B) (MPa)	E (%)	TS (Y) (MPa)	TS (B) (MPa)	E (%)	TS (Y) (MPa)	TS (B) (MPa)	E (%)	TS (Y) (MPa)	TS (B) (MPa)	E (%)
Initial Values	10.1 ± 0.2	12.1 ± 1.8	680 ± 30	10.3 ± 0.4	12.6 ± 0.7	680 ± 25	10.2 ± 0.3	11.9 ± 1.5	680 ± 25	10.1 ± 0.1	12.2 ± 0.7	680	10.0 ± 0.5	12.4 ± 0.6	680
Retained Controls	10.9 ± 0.1	12.7 ± 0.4	610 ± 20	10.5 ± 0.3	12.2 ± 0.4	550 ± 20	10.6 ± 0.1	11.8 ± 0.2	580 ± 25	11.1 ± 0.2	11.8 ± 1.1	540 ± 60	10.4 ± 0.4	11.6 ± 0.3	700
N Exposure (45°)	10.9 ± 0.1	12.8 ± 0.6	600 ± 20	10.8 ± 0.2	11.3 ± 0.9	540 ± 20	10.9 ± 0.2	9.1 ± 1.1	66 ± 21	12.9 ± 0.1	11.6 ± 0.1	< 50	- -	12.8 ± 0.4	< 50

The limits shown are 95% confidence levels.

APPENDIX 3

POLYACETAL - TENSILE RESULTS - CONTROLS

Property	Exposure (weeks)	0	2	4	6 & 7	8	13	16	26	52
Yield Strength MPa		60.81	59.86	59.50	59.89	62.78	60.58	61.68	58.58	62.69
		59.77	59.12	55.12	60.44		60.65	61.90	58.71	60.27
		62.84	59.09	59.34				61.75	58.89	61.57
		59.20		58.86			60.61	62.07	59.15	
		58.76		59.19			60.81		58.80	
	Mean	60.28	59.36	58.40	60.17		60.66	61.85	58.83	61.48
	S.D.	1.63	0.44	1.85	0.39		0.10	0.17	0.21	1.16
	C. of V.	2.70	0.73	3.17	0.65		0.17	0.28	0.36	1.89
Elongation at Yield %		10.16	11.55	11.93	9.85	10.31	10.78	9.47	5.85	9.10
		9.93	11.70	8.00	11.31		10.54	9.77	6.16	8.60
		9.54	13.24	11.93				9.70	5.88	10.20
		10.01		11.85			10.85	11.70	5.68	
		10.16		11.24			10.93		6.00	
	Mean	9.96	12.16	10.99	10.58		10.78	10.16	5.91	9.30
	S.D.	0.25	0.94	1.70	1.03		0.17	1.03	0.18	0.82
	C. of V.	2.56	7.70	15.43	9.76		1.56	10.18	3.02	8.80
Breaking Strength MPa		60.44	58.41	55.37	57.47	57.29	57.32	57.04	54.75	58.63
		59.77	54.84	51.66	57.08		57.66	58.11	56.15	58.76
		62.84	55.56	56.33			60.39	57.83	54.82	58.96
		55.07		54.52			57.68	58.34	54.49	
		55.31		54.96			56.67		55.42	
	Mean	58.69	56.27	54.57	57.28		57.94	57.83	55.13	58.78
	S.D.	3.39	1.89	1.76	0.28		1.43	0.57	0.67	0.17
	C. of V.	5.78	3.36	3.22	0.48		2.46	0.98	1.21	0.28
Elongation at Break %		>10	>10	>10	>10	>10	>10	>10	>10	>10
Modulus GPa		2.381	2.825	2.435	2.539	2.524	2.259	2.404	3.006	2.48
		2.423	2.751	2.413	2.375		2.656	2.455	2.634	2.76
		2.521	2.438	2.519			2.548	2.645	2.306	2.56
		2.551		2.577			2.552	2.341	2.717	
		2.786		2.364			2.474		2.521	
	Mean	2.532	2.671	2.461	2.457		2.498	2.461	2.637	2.60
	S.D.	0.158	0.205	0.086	0.116		0.148	0.131	0.258	0.14
	C. of V.	12.46	7.690	3.478	4.720		5.941	5.326	9.772	0.31

APPENDIX 3

POLYACETAL - TENSILE RESULTS - EMMA

Exposure (Weeks) Property	2	4	6	8	16
Yield Strength MPa	59.89	58.37	58.80	58.28	
	59.68	57.26	59.20	56.06	NY
	60.04	58.00		58.91	
	59.55	56.14	58.65	57.45	
			57.85	57.96	
Mean	59.79	57.44	58.63	57.73	
S.D.	0.22	0.98	0.57	1.07	
C. of V.	0.36	1.71	0.97	1.86	
Elongation at Yield %	9.31	9.70	9.24	8.23	
	9.39	9.00	7.85	6.62	NY
	10.01	8.85		7.93	
	9.00	6.70	8.00	6.69	
			8.23	8.47	
Mean	9.43	8.56	8.33	7.59	
S.D.	0.42	1.30	0.63	0.87	
C. of V.	4.48	15.13	7.52	11.50	
Breaking Strength MPa	59.10	56.79	56.44	57.98	33.85
	58.86	55.97	57.45	55.23	21.92
	59.01	56.95	56.27	58.02	31.33
	57.16	55.38	56.93	56.72	28.53
			56.53	55.78	31.48
Mean	58.53	56.27	56.72	56.75	29.42
S.D.	0.92	0.73	0.47	1.26	4.60
C. of V.	1.57	1.30	0.83	2.22	15.63
Elongation at Break %				>10	1.30
	>10	>10	>10	7.00	0.77
				>10	1.30
				7.54	1.15
				>10	1.30
Mean					1.16
S.D.					0.23
C. of V.					19.73
Modulus GPa	2.690	2.351	2.716	2.621	2.757
	2.702	2.719	2.660	2.466	3.263
	2.535	2.552	2.513	2.267	2.654
	2.618	2.457	2.592	2.268	2.898
			2.710	2.512	2.412
Mean	2.64	2.52	2.64	2.43	2.80
S.D.	0.08	0.16	0.09	0.16	0.32
C. of V.	2.92	6.20	3.25	6.43	11.27

NY: No yield

APPENDIX 3

POLYACETAL - TENSILE RESULTS - EMMAQUA 'A'

Exposure (Weeks) Property		2	4	6	8	16
		59.39	56.25	58.32	56.45	
Yield Strength		59.66	58.32	58.45	57.66	NY
MPa		60.04	58.10	58.26	57.45	
		59.80	58.34	58.17	57.84	
		59.88				
	Mean	59.75	57.75	58.27	57.35	
	S.D.	0.25	1.01	0.12	0.62	
	C. of V.	0.41	1.74	0.20	1.08	
Elongation at Yield		10.24	7.08	7.77	6.62	
%		9.47	9.54	8.54	7.00	NY
		9.62	9.16	7.62	7.16	
		10.31	8.85	7.55	7.08	
		9.39		9.54		
	Mean	9.81	8.66	8.20	6.97	
	S.D.	0.44	1.09	0.84	0.24	
	C. of V.	4.45	12.58	10.30	3.43	
Breaking Strength		59.11	55.60	56.87	56.46	18.86
MPa		59.44	57.67	57.72	57.74	26.66
		58.86	57.37	57.52	57.53	52.71
		58.78	57.23	56.92	57.85	28.01
		59.22		56.75		
	Mean	59.08	56.97	57.16	57.40	31.56
	S.D.	0.27	0.93	0.43	0.64	14.67
	C. of V.	0.45	1.63	0.75	1.11	46.47
Elongation at		>10	>10	>10	7.00	0.54
Break %					9.70	1.00
					9.16	3.61
					9.16	1.00
	Mean				8.76	1.54
	S.D.				1.20	1.40
	C. of V.				13.68	90.96
Modulus		2.383	2.352	2.392	1.994	2.735
GPa		2.377	2.524	2.666	2.345	2.932
		2.597	2.407	2.508	2.722	2.750
		2.570	2.436	2.969	2.123	3.075
		2.675		2.151		
	Mean	2.52	2.43	2.54	2.30	2.87
	S.D.	0.13	0.07	0.30	0.32	0.16
	C. of V.	5.31	2.96	12.05	13.89	5.63

NY: No Yield

APPENDIX 3

POLYACETAL - TENSILE RESULTS - EMMAQUA B

Property \ Exposure (Weeks)	2	4	6	8	16
Yield Strength MPa	57.47	57.78	58.31	58.06	NY
	58.90	57.39	58.25	58.33	
	59.60	58.26		58.42	
	59.84	57.55	58.18	58.44	
				58.86	
Mean	58.95	57.75	58.25	58.42	
S.D.	1.07	0.38	0.07	0.29	
C. of V.	1.80	0.66	0.11	0.49	
Elongation at Yield %	8.16	9.16	7.85	7.39	NY
	8.93	9.16	8.70	9.08	
	10.24	9.93		8.08	
	9.08	8.31	7.93	7.46	
				8.23	
Mean	9.10	9.14	8.16	8.05	
S.D.	0.86	0.66	0.47	0.69	
C. of V.	9.43	7.24	5.75	8.51	
Breaking Strength MPa	56.58	56.89	56.82	57.17	29.15
	56.90	56.67	56.86	56.83	46.08
	57.98	56.57	54.14	57.25	24.97
	58.74	56.75	56.79	57.18	27.14
			57.93	57.31	32.07
Mean	58.96	56.72	56.51	57.15	31.88
S.D.	1.07	0.14	1.41	0.19	8.36
C. of V.	1.81	0.24	2.49	0.32	26.21
Elongation at Break %	9.93		>10	9.39	1.15
			>10	>10	2.23
	>10	>10	5.77	>10	1.07
			>10	9.62	1.00
			8.47	>10	1.38
Mean					1.37
S.D.					0.50
C. of V.					36.88
Modulus GPa	2.669	2.577	2.878	2.649	2.782
	2.697	2.446	2.755	2.219	2.572
	2.578	2.210	2.530	2.242	2.452
	2.448	2.654	2.556	2.700	2.846
			2.773	2.370	2.467
Mean	2.598	2.47	2.70	2.44	2.62
S.D.	0.11	0.19	0.15	0.23	0.18
C. of V.	4.32	7.87	5.55	9.27	6.90

NY: No Yield

APPENDIX 3

POLYACETAL - TENSILE RESULTS - 45° STATIC RACKS

Property		Exposure (Weeks) 4	7	13	26	52
		57.53	58.72			
Yield Strength MPa			58.68	NY	NY	NY
			58.45			
		58.50	56.01			
		58.74				
	Mean	58.26	57.67			
	S.D.	0.64	1.31			
	C. of V.	1.10	2.26			
		7.77	8.00			
Elongation at Yield %			6.85	NY	NY	NY
			7.77			
		9.47	8.00			
		10.39				
	Mean	9.21	7.66			
	S.D.	1.33	0.55			
	C. of V.	14.43	7.15			
Breaking Strength MPa		59.86	57.91	45.08	53.54	43.75
		57.79	57.50	56.84	37.58	28.12
		56.90	56.92	30.73	26.36	51.95
		59.28	54.65	55.37	38.61	21.84
		57.87		29.89	20.97	
	Mean	58.34	56.75	43.58	35.41	36.42
	S.D.	1.20	1.45	12.94	12.59	13.86
	C. of V.	2.06	2.56	29.69	35.55	38.06
Elongation at Break %		8.93	9.85	2.23*	3.00	2.42
		8.70	8.00	7.23	1.34	0.93
		7.30	>10	1.30*	0.74	4.57
		>10	>10	4.69	1.46	0.68
		>10		1.23*	0.60	
	Mean			3.34	1.43	2.15
	S.D.			2.59	0.95	1.79
	C. of V.			77.59	66.79	83.11
Modulus GPa		2.651	2.668	2.407	2.892	2.71
		2.504	2.676	2.360	2.626	3.28
		2.316	2.590	2.709	2.612	2.83
		2.648	2.495	2.460	2.618	3.37
		2.586		2.600	2.730	
	Mean	2.54	2.61	2.51	2.71	3.05
	S.D.	0.14	0.08	0.14	0.13	0.33
	C. of V.	5.48	3.23	5.75	4.64	10.70

NY: No Yield

*3 samples very brittle. End tabs shattered in grips.

APPENDIX 3

POLYACETAL - TENSILE IMPACT RESULTS - CONTROLS

Property	Exposure (Weeks) 0	2 & 4	6	7	8	13	16	26	52
Impact Strength MPa	79.0	84.6	82.3	82.3	83.3	84.5	86.6	85.6	78.5
	78.1	83.7	82.7	83.7		83.8	86.7	86.0	81.2
	77.5	84.7				81.8	86.1	84.1	78.4
	77.9					83.9	78.5	72.9	79.5
	77.7					82.2	85.7	83.0	78.5
	78.0								
Mean	78.0	84.3	82.5	83.0		83.4	84.7	82.3	79.2
S.D.	0.53	0.56	0.32	0.99		1.0	3.5	5.4	1.2
C. of V.	0.68	0.67	0.39	1.2		1.2	4.1	6.6	1.5
Energy to Break Nm	8.5	7.5	3.8	6.2	6.4	4.3	5.4	8.1	6.9
	9.1	6.9	2.7	5.8		7.9	6.8	8.8	8.3
	6.1	4.2				8.7	9.1	4.6	6.4
	11.8					5.8	1.5	9.7	5.3
	5.7					9.1	3.8	6.8	8.1
	3.8								
Mean	7.5	6.2	3.2	6.0		7.2	5.9	7.6	6.7
S.D.	2.9	1.7	0.78	0.28		2.04	2.80	2.0	1.2
C. of V.	38.6	27.4	23.9	4.71		28.6	47.4	26.0	17.9
Stiffness	2.24	2.11	2.27	2.23	2.34	2.38	2.47	2.35	2.21
	1.77	2.27	2.26	2.30		2.29	2.51	2.09	2.07
	1.84	2.20				2.26	2.25	2.16	2.14
	1.78					2.20	2.39	2.08	2.15
	2.14					2.33	2.24	2.37	2.02
	2.23								
Mean	2.00	2.19	2.27	2.26		2.29	2.37	2.21	2.12
S.D.	0.23	0.08	0.01	0.05		0.06	0.12	0.14	0.07
C. of V.	11.5	3.7	0.34	2.2		2.6	5.2	6.3	3.4

APPENDIX 3

POLYACETAL - TENSILE IMPACT RESULTS - EMMA

Property / Exposure (Weeks)	2	4	6	8	16
Impact Strength MPa	53.1	23.0	33.6	30.6	7.0
	67.1	33.7	33.6	32.3	27.2
	58.2	44.3	32.7	30.7	22.3
	81.2	30.8	29.1	30.1	22.4
	67.0	35.0	32.7	29.2	22.3
Mean	65.3	33.4	32.3	30.6	20.2
S.D.	11	7.7	1.8	1.1	7.7
C. of V.	16	23.1	5.7	3.7	38.1
Energy to Break Nm	0.4	0.1	0.1	0.1	
	0.8	0.1	0.1	0.1	0
	0.5	0.1	0.1	0.1	
	1.6	0.1	0.1	0.1	
	0.9	0.1	0.1	0.1	
Mean	0.9	0.1	0.1	0.1	
S.D.	0.5				
C. of V.	55				
Stiffness	2.11		2.30	2.60	
	2.44	2.06	2.31	2.66	NM
	2.06	2.16	2.18	2.44	
	2.13	2.30	2.52	2.25	
	2.14	2.08	2.35	2.32	
Mean	2.17	2.15	2.33	2.45	
S.D.	0.15	0.10	0.12	0.17	
C. of V.	6.9	5.1	5.2	7.1	

NM: Not Measurable

APPENDIX 3

POLYACETAL - TENSILE IMPACT RESULTS - EMMAQUA A

Property	Exposure (Weeks)	2	4	6	8	16
Impact Strength MPa		82.9	39.8	34.3	29.6	25.0
		84.1	44.6		30.4	6.9
		82.6	28.7	28.7	32.2	21.4
		81.1	39.5	25.4	32.2	29.4
		72.0	40.6	40.6	29.4	27.2
	Mean	80.6	38.7	32.2	30.8	22.0
	S.D.	4.9	5.9	6.7	1.3	8.9
	C. of V.	6.1	15	20	4.4	41
Energy to Break Nm		2.2	0.1	0.1	0.1	
		2.7	0.1	0.1	0.1	
		2.3	0.1	0.1	0.1	0
		2.3	0.1	0.1	0.1	
		1.1	0.1	0.1	0.1	
	Mean	2.1	0.1	0.1	0.1	
	S.D.	0.6				
	C. of V.	29				
Stiffness		2.03	2.30	2.35	2.36	
		2.03	2.39	-	2.59	
		2.21	2.12	2.36	2.34	NM
		2.08	2.23	NM	NM	
		2.25	2.14	2.18	NM	
	Mean	2.12	2.24			
	S.D.	0.10	0.11			
	C. of V.	4.9	5.10			

APPENDIX 3

POLYACETAL - TENSILE IMPACT RESULTS - EMMAQUA B

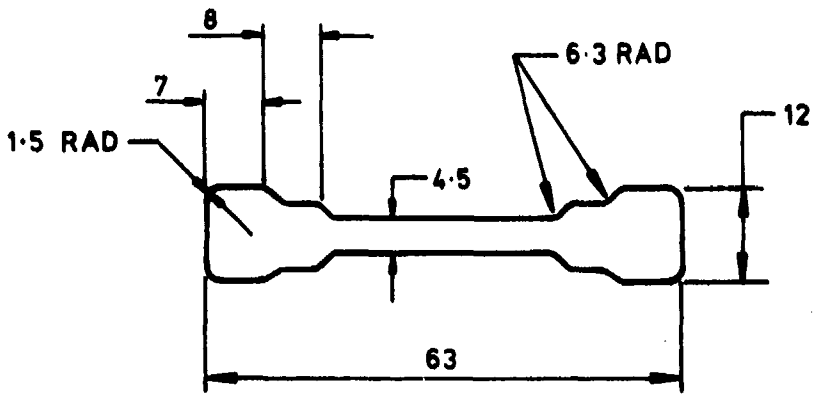
Property \ Exposure (Weeks)	2	4	6	8	16
Impact Strength	48.9	32.2	28.0	33.8	26.9
MPa	47.6	30.2	33.9	29.8	23.6
	48.6	36.2	30.7	26.7	27.0
	46.4	34.7	31.3	32.2	30.1
	51.0	37.2	30.9		12.5
Mean	48.5	34.1	30.9	30.6	24.0
S.D.	1.7	2.9	2.1	3.1	6.8
C. of V.	3.5	8.4	6.8	10.0	28
Energy to Break	0.3	0.1	0.1	0.1	
Nm	0.3	0.1	0.1	0.1	
	0.3	0.1	0.1	0.1	0
	0.3	0.1	0.1	0.1	
	0.4	0.1	0.1		
Mean	0.3	0.1	0.1	0.1	
S.D.	0.1				
C. of V.	20				
Stiffness	2.25	2.20	2.10	2.56	
	2.26	2.23	2.44	2.29	NM
	1.89	1.94	2.30	NM	
	2.34	2.38	2.31	2.34	
	2.32	1.95	2.29		
Mean	2.21	2.14	2.29		
S.D.	0.18	0.19	0.12		
C. of V.	8.2	8.9	5.3		

NM: Not Measurable

APPENDIX 3

POLYACETAL - TENSILE IMPACT RESULTS - 45°C STATIC RACKS

Property	Exposure (Weeks)	4	7	13	26	52
Impact Strength MPa		68.4	46.4	26.7	14.0	13.3
		82.3	48.0	17.7	20.7	17.2
		75.0	39.3	29.4	24.2	15.6
		80.7	52.0	24.7	23.3	15.9
		83.3	56.5	25.7	—	17.5
	Mean	77.9	48.4	24.8	20.6	15.9
	S.D.	6.3	6.4	4.4	4.6	1.7
	C. of V.	8.0	13	18	22	10.5
Energy to Break Nm		1.1	0.3	0		
		1.6	0.3	0	0	0
		1.4	0.1	0.1		
		1.6	0.4	0		
		3.7	0.5	0	—	—
	Mean	1.9	0.32			
	S.D.	1.0	0.15			
	C. of V.	55	46			
Stiffness		2.15	2.28			
		2.37	2.35			
		2.29	2.29	NM	NM	NM
		2.30	2.33			
		1.83	1.89	—	—	—
	Mean	2.19	2.23			
	S.D.	0.21	0.19			
	C. of V.	9.8	8.5			



DIMENSIONS IN mm

FIG. 1 ERDE DUMB BELL

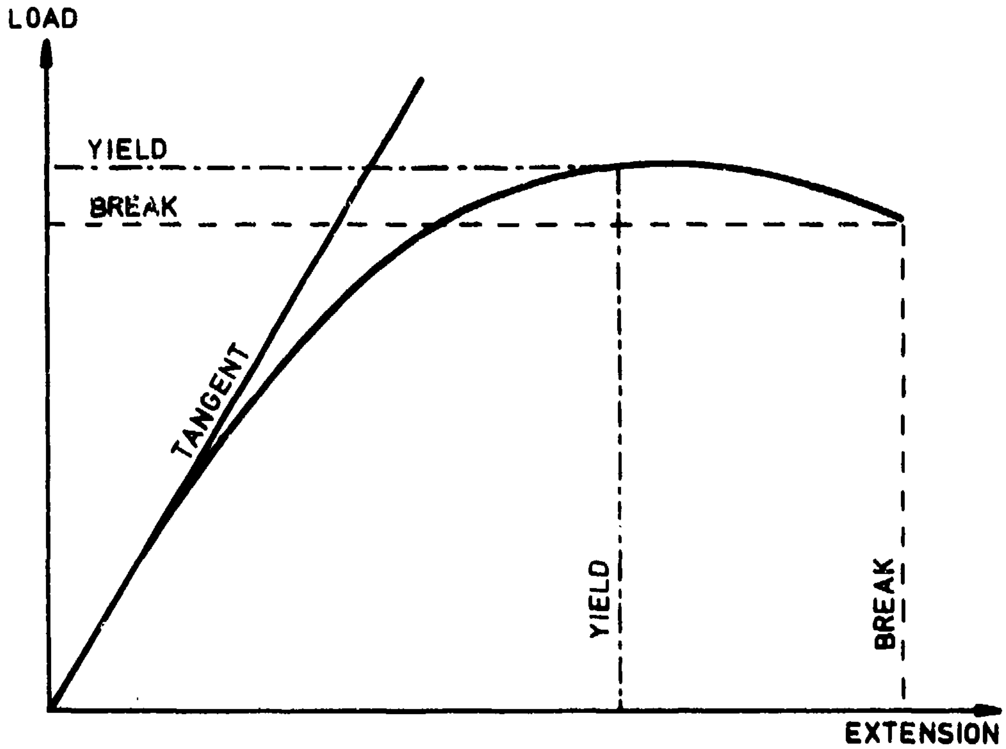
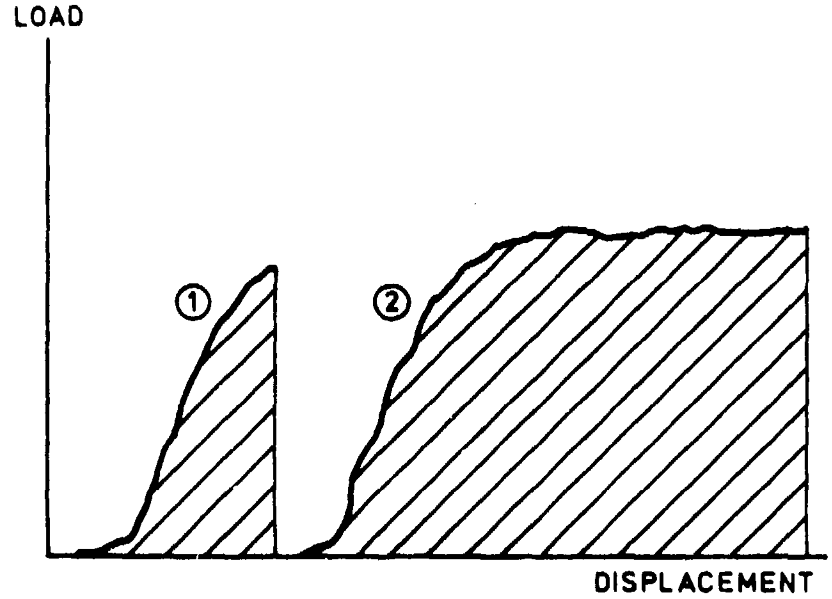


FIG. 2 TYPICAL CHART RECORD FOR A DUCTILE POLYACETAL TENSILE TEST



① BRITTLE FAILURE
② DUCTILE FAILURE

THE MINOR DEVIATIONS FROM A SMOOTH CURVE RESULT FROM THE TEST METHOD. IN THE CASES WHERE THE SPECIMENS WERE VERY WEAK THIS MEANT THAT STIFFNESS COULD NOT RELIABLY BE DETERMINED. SHADED AREAS ARE THOSE USED FOR CHECKING ENERGY TO BREAK.

FIG. 3 RECORD OF TENSILE IMPACT TEST

REPORT DOCUMENTATION PAGE

(Notes on completion overleaf)

Overall security classification of sheet ...... UNLIMITED ......

(As far as possible this sheet should contain only unclassified information. If it is necessary to enter classified information, the box concerned must be marked to indicate the classification eg (R),(C) or (S)).

1. DRIC Reference (if known)	2. Originator's Reference	3. Agency Reference	4. Report Security Classification Unlimited

5. Originator's Code (if known)	6. Originator (Corporate Author) Name and Location
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6 THE FURTHER EVALUATION OF A SOLAR RADIATION CONCENTRATING DEVICE (EMMA) AS A MEANS OF ACCELERATING THE WEATHERING OF PLASTICS

7a. Title in Foreign Language (in the case of translations)

7b. Presented at (for conference papers). Title, place and date of conference

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Descriptors (or keywords)

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(TEST) *Non-TEST term

Abstract

This report is an account of a second trial conducted at Desert Sunshine Exposure Test Inc. using the facility of the EMMA and EMMAQUA machines which are reported to accelerate natural weathering. Low density polyethylene and polyacetal specimens were tested and no real acceleration factors could be found for the EMMA machines over natural 45° exposure.